GLACIATION

OF THE

GREEN MOUNTAINS,

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C. H. HITCHCOCK, L.L. D.

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Glaciation of the Green Mountain Range.

By C. H. Hitchcock.

In commencing to describe a prominent feature in the movement of the glacial ice over the higher mountains of Vermont, one is reminded of the view of the "drift" expounded in "The Geology of Vermont" prepared at the expense of the State under my father's direction and printed in 1861. It was there advocated that the various phenomena had been produced in connection with a deep oceanic submergence. Striae upon the summits of mountains were supposed to have been made by debris frozen into or moved in connection with floating masses of ice. That the highest points of land should have been scored by abrasions passing over them seemed to the older geologists better explained by floating than by glacial ice; for no one had then made clear how ice could move up hill to altitudes of thousands of feet. The ice of living glaciers moves down slopes: how then could the ancient ice have passed over the tops of the mountains unless the land itself had been so low that icebergs could have floated over them? The geologists had the credit of believing many strange stories, but even they hesitated to accept the doctrine that land ice could have been pushed over New England from the St. Lawrence valley. It is not the place here to show how the glacial theory gradually replaced the belief in icebergs and submergence. It is now accepted well nigh universally.

Briefly stated the following proposition may express the condition of things in the eastern part of our continent, so far as our territory was concerned. There was a glacier of continental dimensions, having its starting point in Labrador and sending out streams on every side. Part of it moved towards Newfoundland: more of it slid into the valley of the St. Lawrence,

filled it to overflowing and discharged as readily as possible over the New England heights, the Champlain-Hudson valley and the Adirondack summits. Perhaps the greater portion followed the depressions of the Great Lakes towards the upper Mississippi. The Champlain-Hudson valley was the line of the least resistance, being at a low level and in the direct course, and, therefore, the ice seems to have followed it over a distance of eighty miles out at sea; while the excess pushed southeasterly over New England upon one side and southwesterly over the Adirondacks upon the other. So we may speak of the *Hudson River Lobe of the Labrador Glacier.*

Four mountainous areas exist within the territory named, all of which maintain intimate relations to this glacier. First, there is the inhospitable Labrador tract including the mountains to the far north and the watershed between Hudson's Bay and the St. Lawrence. Dr. R. Bell, (1), states that there are mountains about seventy miles back from Cape Chudleigh apparently from five to six thousand feet high, and the summits near the salt water lie above the influences of glaciation. Quite recently, I have seen the statement made that some of those mountains are fully 8,000 feet in altitude. If so, and the gathering ground is extensive, the problem is greatly simplified. The glacier started from a region capable of sending ice-streams over the valley near by and the distant mountains. Otherwise there has been a resort to two theories; either the land was higher than now in the Labrador district; or else the snow accumulated in such enormous masses that it was itself the high land. Whatever the high land may have been, there is no doubt of the movement of ice in the areas mentioned.

Second, there is the high land of eastern New England, in which lies the culminating point of the whole region—Mt. Washington, 6,293 feet. Its outpost is Mt. Katahdin, almost exactly a mile in height which proves to have been overridden by the ice sheet.

Third, the Green Mountains represent a line of summits trending a little east of north, and very greatly resemble the Blue Ridge of Virginia of which they are the continuation. They have been glaciated from Mt. Orford in Canada to Greylock in

Massachusetts. Connecticut river drains much of the eastern and Lake Champlain much of the western slope.

Fourth, the Adirondacks occupy the most of northern New York. They lie in parallel northeast ranges, with a culmination in Mt. Marcy 5,344 feet. The country is extensively forested, the soil inferior and the rocks granite much like those of Labrador.

Observations have been made of the glacial movements in all these areas, each one of which has its peculiarities. The White Mountain district has received the most attention, nearly all of its peaks having been examined for the signs of glacial occupation.[3] All the higher summits have been abraded by the ice sheet. The Green Mountain area has been visited in part. All the higher peaks present the same phenomena, save that the greater altitude of the New Hampshire summits has been the occasion of a post-glacial accumulation of angular debris, leading the earlier observers to think they were never covered by the ice. The Adirondacks have been studied to a less degree than the Green mountains, and the Labrador country is known the least of all.

I will commence with a full account of all that is known of the Green Mountain region.

The Green Mountain Range.

The Green Mountains are spoken of as commencing in the Gaspe peninsula of Quebec, but for our purpose it will not be needful to speak of them east of the St. Francis river. The range is very low along this stream, from Sherbrooke to Richmond, 485 to 390 feet. The St. Francis rises near the Chaudiere, flows south-westerly till it turns abruptly and proceeds to the northwest, affording an easy grade for the Grand Trunk Railway. The stream is to be compared with the three rivers of northern Vermont which have cut through the range to its very base. The first important rise is to Mt. Orford, 2,860 feet. The line of the watershed descends next to Orford Lake, 961 feet. It rises again to mountains in the north part of Bolton, estimated to be 2,000-3,000 feet high.

The Bolton Gap, 711.

Sutton mountain, 3,000.

Glen Sutton station, Southeastern R. R. (C. P. R.), near the Missisco river, 526.

Irregular rise to Jay Peak, 4,018.

Descent to Hazen's Notch, 1,760.

High mountains in Lowell and Eden.

Descent to the Lamoille river, 541 feet at Johnson.

Sterling mountain, 3,700.

Mt. Mansfield, Chin, 4,348; 4,430 Guyot. The Nose, 4,094.

Winooski river, R.R. Station at Bolton, 345.

Camel's Hump, 4,088.

High peaks in Fayston, unmeasured.

Lincoln mountain or Potato Hill, 4,078.

Road from Warren to Lincoln, estimated at 2,000 feet.

Bread Loaf and Hat Crown.

Road from Hancock to Ripton, over 2,200 feet.

Mt. Horrid, Goshen.

Road from Rochester to Brandon.

High mountains in Chittenden, nearly 3,000 feet.

Commencing with the north line of the Rutland Quadrangle of theUnited States Geological Survey it is possible to follow the crest line of the Green mountains with great exactness through the Rutland, Wallingford, Londonderry, Equinox, Bennington and Greylock sheets to Greylock. I will mention only the more important points.

Road through Mendon, at the watershed, 1960.

Unnamed mountain, 2,856.

Road over the crest in Sherburne, 2,210.

Pico Peak, 3,960.

Mt. Killington, 4241. Given as 4,380 by H. Gannet, Bulletin 76, U. S. G. S.

Little Killington, 3,951.

Shrewsbury mountain, 3,737.

Saltash mountain, Plymouth, 3,278.

Mt. Holly summit on the railroad, 1,515.

South line of Mt. Holly, 2,824.

Highest peak in the east part of Mt. Tabor, 2,881.
Carriage road summit, Mt. Tabor, 2,140.
Highest peak in south part of Mt. Tabor, 2,961.
"Mt. Tabor" in N. W. corner of Peru, 3,586.
Styles Peak, Peru, 3,404.
Road over the range in Peru, 2,440.
Bromley mountain, Peru, 3,260.
Carriage road summit, Winhall turnpike, 2,040.
Mt. Stratton, 3,859.
Carriage road summit, Sunderland, 2,740.
Glastonbury mountain, 3,764.
Peak near south line of Glastonbury, 3,330.
Carriage road summit, Woodford, 2,389.
Mountains in Stamford, 3,063, 3,013.
Carriage road summit, Hartwellville to Stamford, 1,905.
Mountain South, 2,640.
Carriage road, Readsboro to Stamford, 2,400.
Hoosac range in Stamford, 3,014.
Hoosac range in Massachusetts, 2,800.
North Adams, Hoosac river, 704.
Greylock, 3,505.

The following features may be particularized: 1.—The Green Mountain range in Vermont is about 150 miles long, with a considerable uniformity for the higher summits. There is an absence of marked gaps for more than two thirds of the range at its southern end. 2.—There are four valleys crossing the range at its northern part; (a) St. Francis river in Canada; (b) Missisco river near the International Boundary; (c) Lamoille river just north of Mount Mansfield; (d) Winooski river at Bolton. The drainage is to the west or northwest in these four valleys, and the amount of erosion must have been fully 3,500 feet from the crest line down. Opposite the southern two thirds of the range, the drainage on the east is to the south, the Connecticut river. 3.—The lowest of the gaps higher than these river-cuts are near Mt. Orford, 961, in Bolton P. Q., 711; Hazen's Notch, Westfield, 1,760; Mt. Holly 1,515; Hartwellville 1,905. These are "wind gaps." 4.—The highest peak is

Mt. Mansfield 4,430, Guyot. Killington is put at 4,241 on the Rutland Quadrangle but at 4,380 by Henry Gannett in Bulletin 76, U. S. G. S. If the older figure for Mansfield at 4,348 were accepted, Killington would be a few feet higher, 4,380.

THE GLACIATION OF MT. ORFORD.

This summit rises quite abruptly to 2,860 feet, and being at the north end of the range one would imagine the ice current might have been deflected; though it be contrary to the analogy of the neighborhood to suppose it to have been a nunatak, rising above the ice. Thus R. Chalmers says: (4), "Orford Mountain, at the north end of Memphremagog Lake, was found to be glaciated to a height of 1,800 feet. The summit, 2,600 feet high, is bare rock, but no ice action was observed upon it. Owls Head, on the west side of Lake Memphremagog, 2,400 feet high, has not, according to Dr. Ells, been glaciated on the summit either. These and a number of other peaks in this range must have stood up above the surface of this ice sheet as "nunataks" [nunatakr] even during its maximum development."

I visited the summit of Mt. Orford in October, 1897, and reported the results of my observations to the American Association for the Advancement of Science, Boston meeting 1898, (5). Glacial striae were found at intervals to the very summit with a southeasterly direction. Boulders of the Laurentian gneiss from the north side of the St. Lawrence were recognized—a piece of one weighing perhaps fifteen pounds was sent to Professor F. D. Adams of Montreal for identification, and he wrote that the specimen must have come from the north side of the St. Lawrence. The glaciation at the very summit is remarkably well defined.

Our conclusion about the glaciation of this mountain has been confirmed by Principal Dresser, (6). After quoting Mr. Chalmers' statement, he says, "From these conclusions it is evident that the observations on which they are based did not include that dome shaped part of the summit of the mountain which is apparently its highest point. This, which is separated from the highest of the bare and exposed peaks along the front or

southern face of the mountain, by a deep ravine, shows most undoubted evidence of glaciation. Here, near the point where a flagstaff has stood for the past few years, the rock, a fine grained and much altered diabase, is distinctly striated, and the whole eminence has a generally smoothed and rounded appearance. Fragments of clay slate and pebbles of other rocks foreign to the mountain occur here, and boulders of serpentine, evidently from the western base of the mountain, are to be seen in other places near by. The rock appears to have suffered less from atmospheric erosion than at points of about equal height a hundred yards to the south, from which it seems reasonable to infer that it has been protected by a thin mantle of drift, of which the transported rock fragments mentioned above are remnants, which have not been removed by summer rains or forest fires. The direction of the glacial striae, as measured at the flagstaff by Mr. A. H. Honeyman of Knowlton, Que., and the writer, was found to be S. 25° E. magnetic, which fairly accords with the directions given by Mr. Chalmers for striae caused by the greater Laurentide glacier at the foot of the mountain. These range from S. 25° E. to S. 53° E. on the true meridian."

In regard to the glaciation of Owl's Head mentioned by Dr. Ells, I may say that I have examined the summit of this mountain and found no striae, because the rock has deteriorated and the glaciated surface destroyed. I did not, however, make the careful search for marks which may exist, first, because I was not aware of Dr. Ells' statement at the time of my visit and, second, because I found plenty of transported fragments about the summit, which are as good evidence of glaciation as striation.

Dr. Ells has spoken of the dispersion of boulders of the Laurentian gneiss over the whole of the region south of the St. Lawrence, (7), below the elevation of 1500 feet. They extend beyond the International Boundary and water shed into Maine, New Hampshire and Vermont; and have been dispersed by the Labrador glacier which both covered the lowland and swept over the heights.

Principal Dresser writes me that he has also discovered the marks of glaciation upon the summit of Sutton Mountain 3000 feet above the sea. This is the highest point in the Green Mountain range of Canada in the field of our inquiry. I found southeasterly striae upon the summit of the "Pinnacle" in Sutton in 1879.

THE HIGHER PEAKS IN VERMONT.

Jay Peak, 4,018 feet, is the first of the higher summits met with in proceeding southerly from Canada. It was explored by Prof. C. B. Adams, State Geologist of Vermont, who reports striae with the direction S. 40 ° E. on the summit, accompanied by furrows having the same direction.

The glaciation of the summit of Mount Mansfield is described in the Geology of Vermont, 1861, (9). I found striae measuring S. 10 ° E. with a rough stoss side upon certain ledges directed S. 40 ° W. on the Chin. This was in 1859. Mr. A.D. Hager later discovered striae running S. 45 ° E. between the Chin and the Nose, and presented an illustration of the same, adjacent to boulders, which seemed to him to have been the agent of erosion, (10). Prof. Edward Hungerford supplemented the observations of the Geological Report in 1868, (11), upon Mount Mansfield and elsewhere. He found very large transported boulders upon the ridge with striae bearing S. 25 ° -28 ° E.

I visited Camel's Hump in 1859 and found striae running about N. W. and S. E. "The summit illustrates beautifully stoss and lee sides," (12). Professor Hungerford found upon the summit of Camel's Hump fine lines of striation upon knobs of quartz with the directions S. 10 ° W., due W. and S. 35 ° E. About 700 feet below the summit, on the east side, he found striae bearing S. E. and S. S.E."

No one has reported upon the summit of Lincoln mountain. I have repeatedly crossed the range by the Warren-Lincoln carriage road and found no bare ledges upon the summit. Both flanks are covered deeply by till.

Professor Hungerford reports for Mount Killington a "well defined northern stoss side" and saw numerous small boulders

of foreign rock within 20 feet of the highest point. In 1896 I found there traces of the glacial smoothing from the north and N. 30° W. Boulders of the Georgia quartzite were plenty, also a two feet square block of a white quartz conglomerate, and diabase; all from the west side of the mountain.

The region north of Killington must have been extensively traversed by southeastward ice currents, since pebbles and blocks of the Burlington red sandstone are common in the till and modified drift at the lower end of White river and farther south. They are very abundant at the Quechee railroad summit and the Gulf.

In the east part of the Mount Holly gap striae are reported from S. 50°-60° E. In Ludlow and Plymouth there are several similar directions.

TRIP TO MOUNTS STRATTON AND HAYSTACK.

At the request of Prof. G. H. Perkins, State Geologist, I examined the summits of Mts. Stratton and Haystack in 1903, and he accompanied me to the summit of Mt. Stratton. These two mountains are the highest peaks in the southern part of the State, and therefore it was desirable to determine the course of the ice currents upon them.

We found Mt. Stratton completely covered by earth and forest growth. Fortunately a tree had been blown over on the summit laying bare a ledge having striae upon it pointing S. 18° E., magnetic. A quartz knob in another place showed glacial smoothing. Elsewhere several cobble stones of gneiss and quartzite made their appearance so that the evidence was decisive of the transportion of rock fragments over the summit in a direction east of south. There are signs of a local glacier down the valley of the North branch, as intimated in the report.

The summit of Haystack is a sharp cone 600 feet high, the total altitude being 3,462 feet. It is composed of a rough mica schist like that described from Searsburg, with many grooves and scratches running S. 20° E. magnetic. Being almost a bare rock no stones could remain upon it hence there

can be no mention of erratics. Some of the grooves are a foot wide and several inches deep.

THE TACONIC MOUNTAINS.

Such Taconic mountains as Equinox and Eolus (Dorset) do not readily retain the drift markings, though a better search might reveal them. I have climbed only one of them in Vermont. Greylock is one of these summits, though in the line of the Green Mountains. There is nothing equivocal about the marks of the ice here. My father describes them in his report on the Geology of Massachusetts, (13), running east of south and I have verified his observations. More exactly, I found in 1892 striae S. 18° E. at the height of 2,400 feet. The same was found near the top and at the summit. I also found there many boulders of the Georgia quartzite. This is a very hard rock and therefore it is excellent material to illustrate the dispersal of the drift. The south east course in common on the Taconic peaks in Massachusetts, as along the whole western boundary of the State, upon Tom Ball in Alford, Lenox Mountain, etc. Upon Mounts Everett and Washington its course is S. 10° E. and S. 70° E. upon both sides of Hoosac mountain near the tunnel.

OTHER HIGH SUMMITS IN VERMONT.

A few examples of the courses away from the Green Mountains may be of interest. In Berkshire they run S. 8° E., S. 25° E. and S. 40° E. In Sheldon and Enosburg the course is S. 35° E. and S. 47° E. Upon the summit between Roxbury and Warren the striae run S. 31°-55° E. Zadock Thompson mentions several in Huntington from S. 26° to 68° E. Upon Mt. Pisgah 3,800 feet high on the east side of Willoughby Lake I found rather obscure striae S. 30° E. in 1892. Upon Mt. Pulaski in Newbury the course is S. 25° E. The highest land in Windham shows them running S. 20° E.

There are some lines running west of south, especially in the southeast corner of the state, as in Halifax, Wardsboro and Marlboro. At the interesting pot holes on the town line be-

tween Wardsboro and Dover 2,235 feet above the sea the striae run S. 30° W. It is in the col between higher mountains, and must have been the line of the discharge of a lobe of the great glacier. The westerly course is very marked down the Connecticut valley, particularly in Massachusetts and Connecticut and seem to represent an independent lobe of the ice sheet, probably after the ice had reached its maximum development.

Mt. Ascutney 3,186 feet high exhibits two sorts of glacial action. Upon the summit I observed the several directions of S. 20° W. S. and S. 70° E. One fourth of the way up S. 10° E. The rock is not a good one to retain the markings and some of these mentioned have since been obliterated by weather action. Two elements are to be noted. The first is the southeasterly movement common to the higher summits, and this is poorly shown by the striae, but very markedly by the rock fragments that strew the surface in Claremont and Newport, N. H., and elsewhere. The second element is that of the Connecticut valley lobe running south and slightly west of south. The mountain was a sort of measuring pole inserted in the midst of the Connecticut glacial lobe. As the southerly movement has been detected upon the summit, it is clear that Ascutney was not a nunatak but was entirely submerged in the ice-mass in the later period.

GLACIATION IN THE ADIRONDACKS.

In the older literature I find very little said about the evidences of ice action in the Adirondacks. The region lay chiefly in the Second District, reported upon by Professor E. Emmons. Several things were understood by him, (14). 1. The belt of drift along the western slope of the Green Mountains shows a predominance of Taconic rocks, with none of the so called primary crystallines. 2. The middle belt, including parts of the Champlain-Hudson valley and the Adirondacks, is characterized by boulders of hypersthene, gneiss and primary limestone. 3. The western belt, along the St. Lawrence valley, abounds in hypersthene and the granites of the far north. The striae are to the south in the Champlain valley and to the southwest in

the St. Lawrence valley. The work is supposed to have been done mainly by icebergs; and he takes pains to mention his acquiescence in the views of Murchison.

The Third District, reported upon by Professor Lardner Vanuxem, lay to the southwest and south of the Adirondacks, just reaching into the crystalline area. He accepts as the more probable view the glacial origin of striae; and I understand him to teach that the distribution of the boulders in Northern New York was due to radial movements from the central upraised primary mass of the Adirondacks, (15). He assumed that the primary rock boulders of the St. Lawrence valley came from the Adirondacks rather than from the far north. In the description of the county geology he mentions the occurrence of the primary boulders in great abundance in the counties of Herkimer, Montgomery, Oneida, Otsego, Madison, Cortland, Tioga, and even into Pennsylvania. Thus the fact of the southwest movement from the Adirondacks is substantiated by the observations of Vanuxem.

Prof. T. C. Chamberlin presumes from the data in his possession, 1883, (16), that massive currents swept around these mountains both from the Champlain and St. Lawrence valleys, "while a further current, at the height of glaciation, probably passed over the Adirondacks, and gave to the whole a southerly trend."

Mr. Verplanck Colvin presents quite a satisfactory general statement about the glacial appearances of the higher summits. Mt. Marcy is said to be destitute of glacial drift; but its ledges have been rounded as if by ice, while the striae have been obliterated by weathering, (17). The other high peaks are more or less covered by the drift.

On attempting to gain further information, I found independent observations of striae by Prof. H. P. Cushing, upon the north flank of the Adirondacks, which were generally southwesterly. Prof. J. F. Kemp reported a similar direction as prevalent about Moriah, and elsewhere to the west of Lake Champlain. The striae in the Mohawk valley are described by Prof. A. P. Brigham as (18) flowing to the west.

Prof. J. D. Dana in the fourth edition of the manual of Geology, p. 952-4, 1895, presents an unusual generalization; due of course to the lack of precise information. "The ice of the Adirondack region flowed south, southeastward, over eastern Connecticut, into what might be called the realm of the White Mountains and it did this notwithstanding the obstructing Green Mountain range on the route; and this is evidence that the Adirondacks part of the plateau was the higher." "The facts prove that from all western New England the flow was from the northwestward, across the Taconic Range and the Green Mountains, and in a direction from the Adirondack region, or the more elevated Laurentide region beyond it."

Being desirous of obtaining satisfaction as to the actual movement of the ice over the higher Adirondacks, I visited Mt. Whiteface in 1896 and Mt. Marcy in 1898, and presented my conclusions in three brief papers, viz: "The eastern lobe of the Ice Sheet" in the American Geologist, July 1897. "The southern lobe of the Laurentide Ice Sheet," Proceedings of the Toronto meeting of the British Association for the Advancement of Science, 1897. The results of the trip to Mt. Marcy July 7, 1898, were stated orally the same evening to the Appalachian Club at St. Hubert's Inn, (19), and were included in the abstract of the third paper, "The Hudson River Lobe of the Laurentide Ice Sheet," August, 1898, published in the Proceedings A. A. A. S., Boston Meeting. It has been a matter of regret that this last abstract was so imperfect; but its purport did not differ from the first named paper. The discovery of the additional facts at Mt. Orford and the Adirondacks led to the change in the title.

The cone of Mt. Marcy rises abruptly for a thousand feet vertically. At its south base I noted a small esker, which certainly was once connected with a glacier. There seemed to be very little indication of disintegration in the rock of the cone. It is like one grand embossed ledge. Boulders estimated to weigh ten tons rest upon the surface besides many smaller ones and they have the usual shape of glaciated stones. No fragments of Potsdam sandstone were seen. If the boulders

came through glacial transportation they could have come from a distance of more than twenty miles, since it is possible to travel that distance in a northeasterly direction on the same kind of anorthosite as is found on the summit. This peak has probably been glaciated.

The trip to Mt. Whiteface in 1896 proved the existence of southwest striae from Crown Point and Port Henry across to Jay and Wilmington. Mt. Whiteface, exceeding 4,000 feet in altitude, was found to be more or less covered by till carrying fragments of Potsdam Sandstone derived from the north east. Any mass of ice that came from the northeast and covered Mt. Whiteface must have covered also the whole Adirondack region, leading to the general conclusion that a lobe of the ice sheet moved southerly from the Laurentian highlands, naturally following the depression of the Champlain-Hudson valley. As in every glacial lobe there are radial movements to either side, so here the ice moved to the southeast over New England, and to the southwest over the Adirondacks.

The western limit of this lobe may have been at the angle in the terminal moraine near Salamanca, N. Y.; the eastern limit at Cape Cod, unless the land were elevated and the ice extended further to the east. It is probable, also, that the lobe continued down the submerged valley of Hudson River eighty miles beyond New York.

The facts about the glacial phenomena in the Adirondacks are brought out later by I. H. Ogilvie in the Journal of Geology, (20). He supplements the observations of Prof. H. P. Cushing in the northern counties, of Prof. J. F. Kemp in the eastern counties, and those of the Vermont Geological Report of 1861 for Lake Champlain. His conclusions are in accord with what have been already stated for the several districts named. All the striae known to the author are tabulated and presented graphically upon a map. "Not a single record," he says "has been found among the highest mountains. The map shows the three zones of striation: a zone along the Champlain valley where the striae are very numerous and variable in direction: a zone along the gneissic hills where they are less numerous

and prevailingly [from the] northeast; and a zone among the high anorthosite peaks, where striae are entirely lacking, though the mountain tops here are conspicuously smooth." He further remarks; "upon the crystalline rocks of the Adirondacks the direction is uniformly southwest. No striae were observed in this region in other directions, except those which could be clearly shown to be influenced by some topographic variation of local character. There appears to be no change in direction with altitude. The approach to the high and rugged mountains is marked by a conspicuous decrease in the number of striae, which is what would be expected if the ice were stagnant in the valleys." * * * * "The summits, however, have been markedly smoothed; the abundant boulders of Potsdam sandstone on even the highest peaks give unquestionable evidence that the region was entirely buried, and by ice in vigorous motion. The conclusion reached is, therefore, that the ice entered the region from the northeast, flowing on in that direction where open valleys afforded opportunity, becoming stagnant in narrow valleys, and, finally, at the time of its greatest advance burying the region entirely, an upper southwestward moving current passing over the stagnant valley masses below."

PROFESSOR UPHAM'S PAPER.

In 1889 Prof. Warren Upham read a paper before the Appalachian Club, (21), upon the Glaciation of Mountains in New England and New York. All the facts known at that date respecting the marks of glaciers upon the higher summits of Maine, New Hampshire, Vermont and New York were summarized. The present report may be looked upon as the supplement to Professor Upham's very noteworthy contribution. Had it not been for the handicap of several nunataks proposed by the earlier geologists, Professor Upham would undoubtedly have presented the generalization suggested by my later paper.

He says that "New England presents three types of mountains in respect to glaciation, of which the least frequent is exemplified in this district only by Mts. Katahdin and Washington, with the neighboring peaks of the Presidential Range, where the surface has not been swept by the current of the ice-sheet, or, if it were at one time wholly ice- covered, as is demonstrated for Mt. Washington, the time of the glacial envelopment was very brief, not sufficing for the removal of the loose masses which have been fractured by frost from the underlying rock. The second and most common type is represented by Monadnock, where the moving ice-sheet has carried away all the rock fragments which before the Ice Age doubtless presented generally on all our mountain tops the same appearance as the present summits of Katahdin and Washington; instead of which, the surface is now left bare, and rounded in smooth low hummocks of rock on the stoss side." * * * * "A third and infrequent type is represented by the northwest side of Mt. Carrigain, where deposits of glacial drift, analagous to the till of lower areas, cover the bed rock."

It is of course natural to seek for symptoms of weak glacial action upon the highest mountain; especially as it has been held by many geologists in the past that all the higher summits were simply nunatakr, the first named type of Upham. My later studies of the Presidential Range, I think satisfactorily prove that the ice has moved vigorously over every Montalban summit. Except for the debris of later origin, were the levels two or three thousand feet lower, no one would consider the phenomena different from those common at lower altitudes. In the first place, a peak represents a very small area; transported material might happen to be very scant, and however abundant, to have been removed. The rain descending the slopes will wash out the clayey part of the till, and the stones thus liberated are liable to yield to the influence of gravity and descend. Mt. Washington has lost hundreds of the foreign stones carried there by the ice by the hands of Geologists anxious to possess themselves of such interesting glacial relics. The geologists of the year 1950 will not find a single one re-

maining, if the students of the next half century are as industrious as those of the past thirty years have been. Secondly, the angular debris of Washington and Katahdin is the product of conditions prevalent since the Ice Age. The exposure to freezing at the present time is excessive, and is adequate to account for the angular character of the fragments, as it has been no less intense ever since the glacial period. Preglacial disintegration cannot be proved. Third, striae and embossment are as plainly shown upon Mt. Washington as upon the average mountain of inferior altitude. The striae have been measured upon a ledge not fifteen feet lower than the apex, and are common upon fragments of quartz detached from the solid rock by freezing and gravity.

A word as to Katahdin. Quotations were taken from my report of 1861, in which I seemed to insist upon the absence of ice marks upon the summit. Later on I mentioned the fact of finding boulders that must have been carried over the very highest summit. It should be mentioned that I had had little experience in the unearthing of glacial indications at that time. The general rounding and smoothing of the summit is in favor of glaciation; and the inference that the fragments were angular, like those upon Mt. Washington, must have been based upon the account of the debris at the base of a precipice. The summit has no more angular debris upon it than can be seen upon any other New England peak of the same altitude, 5,215 feet, which is a thousand feet less than Mt. Washington's apex. Professor R. S. Tarr has since closed the discussion about the glaciation of Mt. Katahdin by his observations. He found glacial smoothing and transported fragments there.

It seems evident from a review of the facts that neither Mt. Katahdin, Mt. Washington nor Mt. Marcy are to be considered as nunatakr; and hence the first type of mountains, as urged by Professor Upham, must be merged with the second. All the New England and northern New York summits were swept over by the glacial current and the nunatakr must be sought for among the Catskills or some other highland comparatively near the ice-border just as they are in Greenland today.

It is quite interesting to recall how the facts have been gradually accumulated leading to the belief in the existence of the Hudson river lobe of the Labrador ice-sheet. First came the knowledge of the central current from the plain of the St. Lawrence directly south through Lake Champlain and Hudson river through the suggestion of E. Emmons and the measurements of C. B. Adams, in 1842 and 1846. The latter commenced observations upon the southeasterly courses of the striae up the three river valleys of northern Vermont and the single summit of Jay Peak. The Survey of 1861 afforded observations sufficient for a hasty generalization in the belief that the whole Green Mountain range had been thus swept over. This was followed by the conclusions that all the White Mountain summits and a large part of Maine had been glaciated in a similar manner 1861-1877-1892-1894. Meanwhile the Canadian geologists and others showed that the southwest movement along the Great Lakes and farther west covered more territory than the other courses. Prof. T. C. Chamberlin collated all observations previous to 1883 indicating the existence of lobes and the existence of two great forward movements of the ice. The latest part of the field to be explored is that of the Adirondacks, where the existence of the southwest movement is proved, though it was clearly suggested in 1842 by the discoveries of Vanuxem. All the workers in these several districts wrought independently of one another. Although surmised undoubtedly by many glacialists I am not aware that anyone showed the connection between the southeast movement in New England, the southern along the Champlain-Hudson valley and the southwest movement over the Adirondacks previous to my generalization of 1897 in the American Geologist. The existence of a glacial lobe starting in Labrador, flowing down into the valleys of the St. Lawrence, Lake Champlain and Hudson river, filling up these great valleys and then turning to the southeast and southwest over the elevated mountain districts is a grand conception which harmonizes all the observations made by geologists in the eastern part of North America.

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